

CAZONEA 87W01

CAZONEA 87W01

Ontario, Environmental Assessment Board.
Witness Statement No.1
ECOLOGICAL IMPACTS OF TIMBER MANAGEMENT ACTIVITIES.
ECOLOGICAL ISSUES OF FIRE, CLIMATE CHANGE, AIR
POLLUTION, AND ACID RAIN IN ONTARIO FORESTS. /

EA 87-02

IN THE MATTER of the Environmental Assessment Act (R.S.O. 1980, c. 140) as amended; and

IN THE MATTER of a hearing before the Environmental Assessment Board regarding a Class Environmental Assessment for Timber Management on Crown Lands in Ontario.

WITNESS STATEMENT No. 1

ECOLOGICAL IMPACTS OF TIMBER MANAGEMENT
ACTIVITIES

ECOLOGICAL ISSUES OF FIRE, CLIMATE CHANGE,
AIR POLLUTION, AND ACID RAIN IN ONTARIO FORESTS

PREPARED BY

Dr. Thomas C. Hutchinson

INST. FOR ENVIRONMENTAL STUDIES
UNIVERSITY OF TORONTO



3 1761 03882410 8

FILED ON BEHALF OF
FORESTS FOR TOMORROW
a coalition of



The Botany Conservation Group
of the University of Toronto

The Temiskaming Environmental
Action Committee

The Federation of Ontario
Naturalists

The Wildlands League, an Ontario
Chapter of the Canadian Parks
and Wilderness Society

The Sierra Club of Ontario

Earth Sciences Library

Original printed on recycled paper



Digitized by the Internet Archive
in 2025 with funding from
University of Toronto

<https://archive.org/details/31761056888464>

EXECUTIVE SUMMARY

1. This Statement of Evidence has been prepared on behalf of Forests for Tomorrow for the purpose of presenting to the Environmental Assessment Board evidence concerning ecological impacts on forest ecosystems in Ontario of various clearcutting and silvicultural management schemes. Particular emphasis is placed on published scientific papers concerning the nutrition and hydrology of sites before and after harvest and on fire versus clearcut effects.

2. An introduction outlines the scope of the evidence.

Pages 2,3.

3. Examination of numerous reports from widely cited scientists in Europe, the United States and Canada regarding nutrient depletion as a result of biomass (fibre) removal leads to serious concerns that full tree harvesting on moderate to poor nutritional sites will inevitably cause restrictions to the ability of such sites to successfully grow second and further generation forests, in the absence of appropriate fertilizer applications.

Pages 4 to 21

4. Biomass increases from full tree versus bole only harvesting are generally substantially less than the relative increase in nutrient removals from the site, especially for nitrogen and calcium.

Pages 4 to 21

5. Recommendations are made for methods and directions which would ameliorate the worst nutrient and organic losses.

Pages 6,8,10,13,15,19, 20.

6. An effect of clearcutting is to cause site acidification on some sites .

Pages 17 to 20

7. Clearcutting affects water quantity and chemical quantity of discharges leaving a site.

Pages 21 to 27

8. Comments on the B.D. Nicks report for E.B. Eddy Forest Products regarding clearcut size effects are made.

Pages 28 to 31

9. Dr. Tom C. Hutchinson will attend the hearing and give evidence regarding the subject of this Statement of Evidence.

1. INTRODUCTION

In this report a number of issues regarding present forestry practices and silviculture management will be examined and related to various forestry research studies. These include questions relating to long term nutrient impacts on future generation forests following contemporary clearcutting practices using bole only versus full tree harvest, effects of these practises on soil compaction and soil acidification, effects of clearcutting on water quality and quantity in watershed area streams and lakes, and the significance of these practices on nutritionally poor or moderate sites, such as black spruce on muskeg, outwash dry sandy sites, shallow soils etc. The probable occurrence of climatic warming over the next 50 years is also considered as a key factor in sensible management plans by the MNR.

A good deal of the forest ecology inputs presented to the Board in MNR Panel 9 and OFIA/OLMA Panel 6, have been based on a strong contended parallel between post-fire ecology in the boreal region, especially of nutrient losses, harvest removal of biomass from clearcut sites and site conditions for seedling establishment after fire. The stimulation of jack pine germination after a fire has been used to suggest large scale clearances are necessary for healthy forests. The substantial losses of essential key elements for tree nutrition and for plant growth as a result of conventional bole harvests and the much greater losses being incurred on a very large scale in Canada by full-tree harvest have been minimised, sometimes denied, and, at best, suggested to be of small importance compared with site nutritional reserves. The repeated scientific emphasis in many reports on the damaging nutritional losses in full-tree harvests especially for nitrogen, calcium and phosphorus have been downplayed. Many of the

nutritional warnings are coming from researchers with the Ministry of Natural Resources or the Canadian Forest Service.

There seems to be a conflict between the advice given for nutritionally poor sites to not harvest using full-tree removal methods, i.e. on sites such as dry sandy locations, on muskeg, and on moderate nutritional sites, and the implementation of harvest procedures in the field. The problem of competition from hardwood species on cut-over black spruce and jack pine sites seems to be at least in part, a function of harvest practices. Soil compaction is a result of mechanical skidders and more recently of giant feller-bunchers and forwarders, whose tracks and tires cause extreme compaction of the large clearcut sites where full-tree removal is practised. Loss of organic matter, which is a vital nitrogen and nutrient reservoir, is a major drawback resulting from the opening up of clearcuts to light, with resultant microbial changes in the soil and higher soil temperatures. The seedbed of feather mosses, which survive fire to varying extents, are destroyed by these practices causing a major silvicultural problem in re-establishing desirable species for future timber reserves.

The room for errors in management leading to site degradation is very large and the added costs of a more informed system surely more than balance out if a longer term view is taken. Some specific points regarding forest ecology and the impacts of harvest removal techniques and restoration of sites follow.

2. IMPACT OF BOLE REMOVAL AND FULL-TREE HARVESTING ON THE NUTRITIONAL STATUS OF FOREST SITES ESPECIALLY IN THE BOREAL FOREST

Most of the research papers published on forest nutrition and logging impacts have concluded that all essential macronutrients are to varying degrees depleted by the removal from the site of the timber, foliage, bark, roots and branches. The measurements have emphasised potential problems for future supplies of nitrogen, calcium and phosphorus in particular.

Tamm (1959, cited in Weetman and Webber 1972) in northern Sweden calculated for a dry lichen-Scots pine forest that the forest floor contains only 200 kg/ha N in the humus layer. He noted that the N in the B horizon (mineral layer) is largely unavailable to the trees. For such sites, with a low amount of organic matter, and N largely in the organic matter, he recommends avoidance of all practices that decrease the nitrogen content of the soil.

Weetman and Webber (1972) in their studies of full tree logging at Baie Comeau and St. Jovite in Quebec coniferous forests, measured nitrogen losses of 167 kg/ha at Baie Comeau and 387 kg/ha at St. Jovite. These sites were of moderate to good fertility and the researchers noted that the total N reserves in the soil are 1510 and 2024 kg/ha respectively. The N losses are nevertheless 10 and 20% of the total N reserve and re-forestation of the site is dependent on the hope that much of the soil reserve N will become available for tree root uptake. In fact, the potential losses from the open exposed soils following clearcutting are likely to further reduce substantially the organic mat and allow microbial ammonification to the atmosphere as Professor Roger Knowles of MacDonald College, Montreal demonstrated nearly 20 years ago.

In addition, on cutover watershed sites draining into adjacent streams and lakes, various studies have demonstrated a substantial loss of nitrogen as nitrate in the first 3 years after felling. One example of this is the detailed study of Likens et al. (1970) in a mixed hardwood forest in New Hampshire. These Hubbard Brook studies are considered bench marks in our understanding of the functioning of a forest ecosystem following major disturbances. In this study clear felling of the trees occurred but forest floor disturbance was a good deal less than in many of our commercial boreal cuts. However, the trees were left in situ and not removed. Herbicides were sprayed on to prevent regrowth of hardwoods as in Northern Ontario practice. These prescriptions should have reduced nutrient losses into the streams. The researchers found that both the quality and quantity of the water in the run-off streams changed following a November-December 1965 cut. The annual run off of water exceeded the expected (in a nearly uncut watershed) by 39% during the first year and by 28% in 1967. This means the terrestrial site became much drier and the extra flow removed additional soluble nutrients even though the cut trees were kept on site. In the summer months the greatest increase in flow occurred, this being an increase of 4.14 fold in 1966 and of 3.8 fold in 1967.

The deforestation resulted in large increases in streamwater concentration except for sulphate, bicarbonate and ammonium. Very large losses of N occurred via the streams in the first year following the cut i.e. 41-fold in 1966. This loss of nitrate, an element often in limiting supplies for tree growth throughout the boreal and hardwood forests of eastern North America, then increased to 56 fold in 1967. This was largely due to breakdown of soil organic nitrogen to inorganic (and soluble)

nitrogen as a result of altered microbial activity.

The stream dropped from a pH of 5.1 in 1965 to 4.3 in 1966. Algal blooms occurred in the nitrate enriched streams and some essential trace metal elements were leached from the soils e.g. zinc and manganese. Aluminum, an element of potential toxicity to tree roots at quite low concentrations (e.g. Hutchinson et. al. 1986) increased in the acidifying forest soil and in the stream.

Likens et al. (1970) point out that this induced leakiness of a forest ecosystem as a result of clearfelling is in the opposite direction to the normally tight cycling of essential elements in a healthy natural system. It can be thought of a stress response, rather like bleeding or haemorrhaging and it will reduce the subsequent fertility of a site.

In the case of the studies of Weetman and Webber (1972), the challenge for forest management is to determine whether the absolutely inevitable depletion of nutrient reserves at the site can be adequately replaced by tapping into the total reserve of N, for example in the soil; to the extent that a comparable tree growth and biomass can be achieved in the second rotation. If it cannot, then to proceed without remedial measures is to guarantee a non-sustainable response to timber removal. This ignores for the moment all the other plants and animals of the forest and their equal requirement for adequate nutrients and suitable habitat.

Returning to Weetman and Webber (1977) they point out that a serious drawback to whole tree harvesting from a forest nutritional view is that the removal of slash, tree canopy with leaves and needles, branches and bark is a major drain on the sites. Indeed they suggest that the lack of slash on the ground, with its nutrient reserves, following full-tree harvest may be

of critical importance on sites of low nitrogen fertility. They point to such sites as dry sandy sites, (often occupied by jack pine forest) and muskeg dominated by black spruce as sites where it is undesirable to use full-tree harvest. However, such sites are subject to full-tree harvesting in Ontario.

Weetman and Webber (1977) in Table 5 on p. 363 also present data on phosphorus losses which show substantial degradation i.e. losses of 277 to 1293% times the exchangeable soil reserve, and on p. 364 they show that for their study area full-tree harvesting losses of calcium are also high, with values of 12% and 41% of the total soil reserves. They note that the anticipated replacement of calcium may not come about quickly as calcium release from the weathering of granites and gneisses will be very slow during a single tree rotation.

Other researchers have pointed out the magnitude of calcium losses and the potential need to fertilise following bole or full-tree harvests. Calcium is required as a structural component of plant cells, a key component of bark, leaves and wood, and is essential in plant and animal membranes. It also plays a role in encouraging the microbial populations associated with nitrogen fixation.

Freedman, Morash and Hanson (1981) examined the effects on nutrient losses from a site due to full-tree harvesting (which they call whole-tree harvesting) of red spruce - balsam fir in Nova Scotia. As in many other reports in the past 15 years, their study indicates that biomass increases from whole tree extraction were increased over bole only extraction i.e. by 30 per cent in their studies, while nutritional losses were relatively much greater. The authors did not seem to consider that the site loss of

magnesium, nitrogen, phosphorus and potassium presented major problems for a second crop. I consider their view optimistic given that for one site 41 per cent of the total soil reserve magnesium was removed from the site, and for phosphorus 84 per cent, and for one site 112 per cent potassium. However, the loss of 234 per cent calcium from one site and the high percentage losses of the soil reserve for several other nutrients caught their attention. This caused the issuing of a curious warning in Freedman's 1990 paper:

Overall, it appears that for typical forested sites in Nova Scotia, several intensive harvests of forest biomass would probably be required before serious nutrient limitations would develop. A possible exception to this generalization is for calcium, which is present in small quantity in many forested sites and which could potentially be depleted relatively rapidly. (p. E.53)

My own conclusion from this same data base is that tree growth could reasonably be expected to decline precipitously in a second generation and that the site may for the foreseeable future be unable to develop a useful cuttable timber crop. He does warn in his 1990 paper against intensive harvesting on such sites and suggests selection cutting or at worst bole only clearcutting. This may still be overly damaging.

Perhaps we should focus on these sites which can sustain or be made to sustain forest development and not destroy the forest ecology of non-sustainable sites.

The paper of Timmer, Savinsky and Marek (1982) is one already discussed by Dr. K. Armson in these hearings. They studied four forest stands in the Nipigon region, comprising a) young balsam fir b) young hardwood i.e. aspen and birch c) two old (126 year old) black spruce stands on a deep mineral soil and on shallow bedrock. They concluded that in three of the four sites

intensive logging would lead to deficiencies in phosphorus, potassium or calcium in the succeeding rotation.

In terms of biomass removal as a result of full tree harvest, compared with conventional bole only removal, the increases in biomass from their four sites were +116 per cent for the balsam site, +43 per cent for the aspen-birch, +50 percent for the deep black spruce, and +60 per cent for the shallow black spruce. Also, there are rather large increases in removal of biomass which involve loss of litter, slash, foliage, branches, bark, etc. The effect on nutrient removal from the sites was even more dramatic, as outlined below (p. 141, Table from their paper).

Percentage increase in nutrients removed by full-tree compared with bole-only harvest

	Balsam Fir	Hardwood	Black Spruce Deep soil	Black Spruce Shallow soil
N	234	97	107	102
P	221	86	83	97
K	223	101	162	166
Ca	176	89	59	70
Mg	175	91	89	106
Mean	205	93	100	112

These data are used to calculate how long in a second generation forest, the total rooting depth nutrient reserves after bole and full tree harvests will last. For balsam fir with full tree harvest, there is only sufficient potassium for 38 years and calcium for 78; for the hardwood site full tree harvest leaves only 25 years supply of phosphorus and 47 years for potassium, and for the black spruce on the shallow site, calcium is only sufficient for 35 years with full tree harvest. Since these times are shorter than a rotation of 50-60 years, it will be impossible to repeat the cropping satisfactorily. It is noteworthy that this rotation arises in

three of the four sites examined. Despite the economic efficiencies of full tree harvest, it is surely apparent that on all but the most fertile sites, it is a sure way of severely degrading the forest and guaranteeing their non-sustainability. It is also true that Timmer et al.'s estimates are rather optimistic as they assume all calcium, potassium etc. in the rooting depth will be available for plant uptake, while weathering and mineralization can be very slow. The authors of the paper comment as follows:

The results show that conventional tree length logging makes only modest demands on site nutrient capital; sufficient nutrients remain on site to sustain a second generation of trees. On the other hand, shortages of Ca, P, and K will occur on the shallow spruce, hardwood, and balsam fir sites respectively, when harvested by full-tree methods. Calcium losses on the shallow soil black spruce site were the most severe, exceeding soil reserves by a magnitude of 2.5. Weetman and Webber (1972) regarded such losses on a black spruce site in Northern Quebec as serious since calcium indirectly stimulates the mineralization of nitrogen in the humus layer. (Dahl et al. 1967) p. 143

They go on to say that, as we move to more rapid rotations, the situation gets worse.

Predictions like those suppose that future crops are grown at rotation lengths equivalent to the previous crop. This may not be realistic, however, considering current trends towards more intensive fast rotation forest management. Sufficiency periods will be drastically reduced if rotation ages are shortened by modern silvicultural means without using adequate fertilization. For instance, if an equivalent volume of black spruce on the shallow site could be grown in half the rotation age (63 versus 126 years), soil calcium will probably become limiting in 17.5 instead of 35 years. (p. 143)

Areas of shallow soil black spruce which comprise a large part of the Nipigon area (Marek 1975, Jeglum 1980) may be the most susceptible to nutrient depletion by mineral crop utilization. (p. 144)

It is also worth noting the recommendations that Timmer, Savinsky and Marek made in the 1982 paper, the reporting of an MNR research contract:

It is recommended that:

- conventional logging methods be used exclusively on fragile, shallow-

till sites

- full-tree and complete tree chipping operations be restricted to stands supported by relatively deep mineral soils
- marginal sites which are sensitive to full-tree or complete-tree logging be harvested in the winter with snow present
- hardwood sites to be harvested by full-tree methods in the dormant (leafless) season
- mechanical flailing or delimbing devices be operated on sites which are sensitive to intensive harvesting
- rapid generation or active revegetation be ensured after full-tree chipping to accelerate nutrient capture and site recovery processes; and
- intensive, short-rotation forest management be restricted to the deeper, more productive sites in the Lake Nipigon-Beardmore area (p. 145).

It would be reassuring to think these recommendations have all been rigorously implemented and that full-tree harvesting is now restricted to deeper, fertile sites, and that foliage especially is not being removed from sites, but this is not so. To do otherwise than the above is to knowingly or wilfully degrade our forests.

In a further study of nutrient removals through harvesting, Gordon (1982) compared fully stocked black spruce on peat and moist outwash sand and compared them with two boreal mixed-wood ecosystems, consisting of white spruce, balsam fir, white birch, and aspen of moderate and high productivity. He also compared these systems with a northern red spruce system. He comments from his data as follows:

The areas in the boreal forest now being harvested by full-tree and whole-tree harvesting methods are massive. To conserve nutrients, harvesters should be utilized which strip the branches from the bole or leave them on the growing site. How or what we harvest will have substantial effects on subsequent rotation ages. (p. 9)

Gordon points out that leaching losses following crop removal will be large in the first few years and that such losses of nutrients are in addition to those removed with the trees harvested. Regeneration following harvesting enhances nutrient uptake, tightens up the cycle and reduces losses rather

quickly but losses may still continue to exceed inputs for several more years. This circumstance will have the effect of extending (nutrient) replacement times. The extent and type of site preparation and the level of herbicide use may also extend this period.

Other points which Gordon makes which I consider important, are: From his studies, in all cases, almost half of the total organic pool above and below ground are in the standing crop. When total reserves, i.e. organic plus mineral soil mass were considered in relation to standing crop, only black spruce on peat supported a crop nearly as great as the reserves. This lack of adequate reserve could make these sites vulnerable under full-tree harvesting.

Stores of phosphorus on black spruce outwash and peat sites and potassium in all sites but one of the mixed-woods were greater in the standing crop than in the reserves. It is on these sites that nutrient stress can be expected following full-tree harvesting. Finally, Gordon states:

Since most harvesting in the boreal forest is now full-tree, with whole-tree harvesting becoming much more widespread, it is advocated that harvesters be used which strip the branches from the boles before extraction and leave them on site. This will retain substantial nutrient capital on site and particularly important on outwash sands and gravels and peat sites (p. 115).

He says this should be done on moderate to low fertility sites. Page 114, 2nd para, not merely on sites of very low fertility. Alan Gordon is an experienced researcher with the Ontario Ministry of Natural Resources.

At the risk of being repetitive, I want to draw attention to additional studies which all point in the same direction, i.e.

- that bole harvest is much less exploitive of nutrient reserves than full-tree harvest,
- that leaching losses of nutrients after harvest are significant additional losses, especially for nitrogen and calcium,
- that loss of organic matter is a serious degradation for nutrient reserves, for future establishment of a forest and for prevention of erosion, and;
- that removal of foliage and branches constitutes a serious site depletion.

Malkonen (1973) examined nutrient losses due to tree harvest in pine and spruce stands. In the pine stands, full tree harvest increased losses of N or P by 2.5 times that of bole-only harvest and in spring the P loss was increased 5 fold and N 4 fold.

He comments for his particular New England sites that the nitrogen loss caused by the full tree harvest does not appear large compared with the amount of N in the soil. However, in his stands there is already a lack of available N. Most of the N is bound in relatively stable humus compounds which are decomposed much more slowly than logging residue. A considerable amount of the available nitrogen for the next crop is apparently derived from the decomposed logging residues. Accordingly, the nitrogen in the logging residues is considerably more important for the fertility of the site than is apparent from a mere comparison between the amount of N in the logging residue and the soil. The loss of organic material and N through full tree harvesting may be especially serious on infertile mineral soils where small amounts of humus set the potential limits for N mobilization.

The loss of nutrients due to timber harvest is not limited only to those removed with the crop. Especially in soils through which water permeates relatively easily, the leaching of nutrients has been found to be intensified after harvesting by the mineral water percolating through the soil. (p. 382)

He goes on to comment that in order to maintain the fertility of forest bores it may be necessary to replace the nutrients by fertilization.

Freedman, Duinker and Morash (1986) report a study for Nova Scotia in which nutrient and biomass removals from site by bole harvest versus full tree harvest were compared. In this study 4 conifer and 4 hardwood stands were studied in central Nova Scotia. They report the additional biomass and nutrient reversal by whole tree harvest as follows (averages for the sites):

Biomass	50% extra
N	170%
P	200%
K	160%
Ca	100%
Mg	120%

Relative to the total soil store they suggested only calcium depletion was a problem for the second generation. However, one only needs one factor to be limiting to growth to have a problem. Inadequate calcium is sufficient. For their black and red spruce sites, full tree harvest increased calcium removal from the site by 1.9 times in each case.

Weetman and Algar (1983) reported on effects of full tree and bole harvesting of sandy soils and black spruce sites on lithic humo-ferric podzols overlying granite in Quebec. They found that for the 200-year old black spruce stand or the 53-year-old jack pine stand, the data indicated (again) greatly increased nutrient exports from full tree as compared with tree-length logging. The ranges of increases were:

N	288-390%
P	250-533%
K	51-238%
Mg	44-348%
Ca	48-183%

Their ranges are similar to those noted in Finland by Malkonen (1973) already referred to, for N and P. Weetman and Algar state:

Boreal forests are known to be deficient in N supply and respond to N fertilizer additions. Poorer sites have lower humus N reserves, which are potentially the most available N sources for trees. The data from the poor Cladonia-jack pine stands indicate that full tree logging could cause a severe loss of potentially mineralizable N supply in organic matter from slash removed in logging. (p. 1036)

A more recent contribution by Timmer and Ray (1985) is also relevant. In this, they report on a nitrogen limitation for black spruce. They carried out fertilization trials on 29 mature black spruce stands growing on diverse Ontario Claybelt sites. Using diagnosis by vector analysis of current needle responses in terms of dry weight increases and macronutrient concentrations and contents of needles, they found that of all the nutrients which they added, nitrogen was the most commonly and severely limiting for black spruce. Interestingly, they found that their nutrient diagnostic correlated fairly well (probability of 0.71) with the Forest Ecosystem Classification Co-ordinates, indicating that the axis represents a continuum of nitrogen availability.

In an even more recent review, together with a description of some experiments, Maliondo (1988) of the Canadian Forest Service reports on "possible effects of intensive harvesting on continuous productivity of forest lands." He notes three potentially deleterious effects. They are:

- a) the loss of organic matter
- b) the loss of nutrients, and

- c) the occurrence of soil and site acidification.

He goes on to list other damaging effects reported from intense harvesting.

These include:

- a) an accelerated post-harvest leaching of nutrients from the site
- b) the over-occurrence of soil compaction on site due to manoeuvring of logging machinery
- c) the exposure of mineral soil and the occurrence of subsequent erosion, especially on sloping sites, and
- d) the shift in decomposer microbial populations.

In his review section, which is copiously referenced, he notes for organic matter losses (p. 2) that after the canopy is removed more light reaches the ground and the canopy loss means a virtual elimination of evapotranspiration of water, and a consequent increase in moisture (rain and snow) reaching the forest floor. In bole-only harvests slash protects the forest floor and also provides a mulch which absorbs the moisture. In full-tree harvests, this mulch is gone, exposing the soil to summer-time baking, and to gullyng during rainstorms or springtime snowmelt. The normal microbial decomposers which utilize the forest floor litter and slash, experience a depleted nutrient and lignin content in the soil, and often a changed pH, and are exposed to high temperatures. The organisms in place in the forest floor to recycle the essential elements by decaying organic debris are radically changed.

Maliondo references Anderson (1986) who studied an intensively harvested plot under conifers in Scotland. He discovered within 18 months of harvest that 15 cm of forest floor was lost. This was twice the amount of forest floor lost under a conventionally harvested plot.

He reviews literature indicating an increased base cation loss from full tree harvested sites (i.e. calcium, magnesium, potassium) and points out that the magnitude of it depends on the age of the stand; its species composition; and the quality of the site. Young stands have a higher base cation concentration, especially because the amount of crown to bole is relatively high. Consequently, harvesting younger stands and removing the crown from the site maximizes base depletion. Regarding species, hardwoods have higher nutrient concentrations in their tissues than softwood, especially in their foliage. Fir has higher concentrations than black spruce. Accordingly, removal of foliage of hardwoods from site is particularly damaging (as in the St. Lawrence-Great Lakes Forests) and should be avoided at all costs. He concludes relative to sites that are poor sites, that removal of base cations with the crown components may represent a large proportion of the total site nutrient capital.

Maliondo points out that soil and site acidification occurs naturally as a result of tree growth, especially in coniferous sites where the needle litter is itself acidic. In contrast, most hardwood forests have a less acidifying litter. Site acidification will occur as a result of growth, via the removal of bases from the surface soil to the living tree at the root surface. These base removals are balanced by acid exchange. In the natural forest or after a forest fire, these bases are returned to the soil by death of the trees, so the natural balance is restored. Indeed, after fire sites often show a quite large increase in their soil pH.

Atmospheric acidic inputs due to polluted air masses (acid rain and snow, acid fogs) have caused additional acidification of soils. (Tyler, 1985; Tamm and Hallbacken, 1985), in coniferous forests in southern and

central Sweden. These changes are substantial over the past 30-40 years, up to 0.5 to 1.0 pH units. Such changes in already rather acid soils, releases the phytotoxic element aluminum into soluble form in the soil solution, where it can disrupt root growth, mycorrhizal associations and microbial populations, especially those involved in nitrogen fixation.

Maliondo says:

Both conventional and intensive harvesting result in the opening of the canopy allowing more acid to reach the forest floor. However, the base-rich crown components left on the site in conventional harvesting help to buffer the soil from the effects of atmospheric acid input. Intensive harvested sites lack this protection and accordingly may be more acidified. Also, the base-rich crown components left on the site during conventional harvesting add more base cations to soil capital upon decomposition. This source of base cations is reduced in intensively harvested areas. Both the reduced buffering against atmospheric acid inputs and base depletion, as a result of the removal of crown components in intensive harvesting, may lead to lower site productivity (p. 3).

As a result of intensive harvesting, increased rates of organic matter decomposition occur, leading to an increase in acid production. This is especially because of the microbial driven oxidation of organic S and N compounds to organic and inorganic acids. Accelerated leaching of cations then occurs in association with the excess nitrate and sulphate anions being released. The acids percolate through the soil, carrying bases out of the soil into the drainage water. High acidity also increases the amount of soluble (labile) Al and H^+ in the rooting zone (Fuller et al. 1987, and Ulrich 1983). This is again site degradation due to acidification, so that site is less suitable for a second generation of forest.

Maliondo (1988) refers to the work of Nykvist and Rosen (1985) who studied the effects on nutrient pool and humus reserves over a number of years following cutting. The sites were cut in the 1960s in central and

northern Sweden, in natural Norway spruce forest or in spruce plantation. Two series of experiments were made. In the first the depth and chemistry of the humus layer were measured in samples between 6 and 21 years after clear-felling. In the second, humus and mineral soil to 20cm below the mineral soil surface was sampled at sites in the north and south of Sweden. The study compared bole harvest areas with a full-tree harvest equivalent in which all slash was removed from the site. The sites were all initially acidic, in the pH range 3.6 to 4.79. Bole harvest caused a rise in pH at all sites, despite removal of the boles from the site. This increase in pH occurred to a soil depth of 20cm and reflected pH changes of 0.5 to 1.0 pH units in humus layers, where slash accumulated and decayed. This reflects nutrient recycling and an accumulation of bases in the surface layers. The pH increases commenced in the first year after cutting and, dependent upon site, were sustained for 10 years, sometimes for 16 years after clear-felling. In contrast when slash has been removed from the clearcut site together with the boles, then a markedly changed situation occurred. Instead of an increase in pH of 0.5 to 1.0 pH units on average, an average pH decrease occurred of about 0.1 pH units; i.e. the sites acidified. Nykvist and Rosen measured the nutrient elements, the base saturation of the soils and found that the pH increase could be accounted for by release, in water-soluble form, of elements such as calcium, magnesium, and manganese. In the slash removed plots however, the effect of removal was so great that nutrient depletion by the harvest method left insufficient bases to counter the acidification processes. They found H and Al ion increases in the soil solution, both of which are potentially phytotoxic to tree roots and to many ground flora species. To put this in perspective, with conventional harvest

methods on nutritionally adequate sites and with a healthy soil microbial population, sufficient generation of base nutrients can be expected to allow an adequate supply to re-establish a forest on the site and their release will cause a pH increase, more favourable for root growth and mycorrhizal function. When slash is removed from the site, this favourable situation is destroyed. Soil acidification occurs, unfavourable for a healthy decomposer microbial population, unfavourable for root growth, unfavourable for mycorrhizal establishment, and in a direction leading to potential aluminum toxicity. The slash removal also takes away a high percentage of essential nutrients, as repeatedly shown in studies referred to above.

To add to the weight of scientific findings disclosing a very substantial additional nutrient depletion from sites where full-tree harvesting is used, Maliondo (1988) in his review goes on to describe results from harvest experiments in Nova Scotia and New Brunswick. He also provides a large Table 1, pp. 6-10, which list numerous studies (54 in all) from many parts of northern Europe and North America, and even Australia, which all show a large percentage increase in loss of bases as a result of intensive harvesting. These harvests rarely involved the extreme whole-tree harvest method involving root removal, nor of humus and ground flora removal, so are very largely full-tree harvest methods. His own results showed an increase in base losses from 82 to 283 per cent over bole-only methods. His literature survey, which includes several of the papers already referred to above, included many forest types, both hardwoods and softwoods, and forests of widely different ages. Hardwoods showed an increased base loss of 19-217 per cent while conifer additional losses were from 57 to 585 per cent.

This seems to me to be overwhelming evidence, all in the same direction. While the specifics of base loss are generally measured as losses of calcium, magnesium and potassium in the quoted studies, many report losses of phosphorus and nitrogen also. The overall effect is a directed attack, as a result of full-tree harvesting, on the very nutritional resources essential for forest sustainability.

Most studies did not consider those trace or micronutrients which are equally essential for maintenance and growth. These include manganese, boron, molybdenum, zinc, copper, iron, cobalt, and selenium. I have a serious concern based on our own studies and on discussions with colleagues in forest ecology and nutrition in Germany, Sweden and Norway, that we can readily and almost inadvertently cause growth limiting micronutrient deficiencies of such elements as zinc, manganese, boron and copper. The Swedish foresters such as C.O. Tamm and F. Anderson already report zinc and boron deficiencies attributing this, in part at least, to acid leaching losses from their forest soils.

A review by Mahendrappa et al. (1986) on nutrient cycling and availability in forest soils, has been used by MNR representatives to defend a viewpoint that a great deal needs to be learned as to the extent that soil nutrients are available for tree uptake, and that in fact we know very little. The review did not deal with forest harvests but rather with nutrient cycling in the intact forest. It therefore is in no way in conflict with the body of literature reviewed above. Indeed, Maliondo who has carried out the literature review on base losses due to full-tree harvest methods, did this as a post doctoral scholar under Dr. Mahendrappa's direction. The need for a better understanding of nutritional processes is

not in dispute.

3. CHANGES IN SITE HYDROLOGY FOLLOWING CLEARCUTTING

I have outlined above the research in New Hampshire in a mixed hardwood site at Hubbard Brook by Likens et al. (1970). In it, large increases in watershed run-off were reported in the first two years following a mid-winter clear-felling of the trees. Nutritional losses of nitrate, calcium, magnesium and potassium were even more elevated relative to run-off from an uncut section of the same watershed. Cutting and leaving the boles on site is an unusual technique, clearly not a forestry technique. Therefore it has been legitimately argued that such an approach is unsuitable to draw comparisons about effects of an actual forestry harvest on site watertable drawdown, and about effects on stream chemical quality and discharge.

In order to test the generality of their findings at Hubbard Brook, Likens, Pierce and Bormann, beginning in 1970, examined numerous commercial clearcutting operations using bole-only removal systems, in the White Mountain National Forest. In Martin, Pierce, Likens and Bormann (1986) they report on their overall findings of this clearcutting on stream chemistry.

The areas were covered with second growth hardwood-red spruce forest 50 to 100 years old. The hardwood species were 1-40 per cent sugar maple, 8-17 per cent yellow birch, 15-77 per cent American beech, with 3-30 per cent red spruce and balsam fir. The sites were upland ones on sloping land. By monitoring year round flow rates and water quality of weirs on outflow streams, they developed chemical budgets for four years on nine watersheds that were completely clearcut and on an additional adjacent five equivalent but uncut watersheds. Overall, and in every case, commercial clearcutting

of northern hardwood forests in New Hampshire caused accelerated loss of dissolved nutrients to streams. The losses and patterns were similar to those they reported earlier from their own experimental clearcut at Hubbard Brook. Greatest losses in nutrients occurred in the second year following cutting, with a general decline to reference levels by the fourth year. Nitrate, calcium, magnesium, sodium and chloride, all showed significant rates of loss in the streams of clearcut areas, peaking in the second year. Potassium losses did not peak and were unabated at the end of the fourth year. Sulphate levels decreased in run-off from clearcut sites. Where aluminum was measured in discharge waters, it increased. The writers say:

Removal of the canopy by harvesting may contribute to the increased acidity of the streams during the first year after clearcutting. Many forest streams in New Hampshire are currently marginal for trout production because of the low pH and high concentrations of aluminum. A further decrease in pH, even for short periods, may be detrimental (p. 10).

Nutrient concentrations in streams draining clearcuts decrease distinctly and proportionately as the size of the watershed cut becomes smaller. Dilutions occur as water with low concentrations of nutrients enter the streams from uncut areas either from tributary streams or from subsurface flow. They note:

If it is desirable to clearcut larger proportions of a watershed (than the 10-15 per cent they suggest) it would seem prudent to harvest in a series of small cuttings spaced at least two years apart. The two-year spacing would minimize the synchronization of maximum nutrient loss the second year after cutting over large areas of a watershed (Hornbeck et al., 1975, p. 10).

The losses they tabulated for the nine watersheds were less than those noted earlier for their experimental Hubbard Brook study. Over the four years post-cut, losses are estimated as, on average 57, 61, and 15 kg/ha for N, Ca and K respectively, and constitute about 70, 98, and 23 per cent of

the annual estimated uptake for these elements by a forest. These losses are from conventional clearcutting, not full-tree or whole-tree harvesting. They also are of losses through drainage (leaching) from the site and do not include the amounts of elements removed in the wood. At least for the New Hampshire sites, these losses seem significant in quantity.

Sopper (1975) presents data on clearcutting, herbiciding and fertilizing on water quality in streams in Pennsylvania and elsewhere. While he concludes that negligible effects follow clearcutting, he bases this on data on concentrations in streams, while ignoring the increased quantity of water that leaves the site. Some of the examples he uses to reassure the reader that "in general, research results indicate that nutrient losses, particularly nitrogen, following forest clearcutting, are small to negligible" (p. 24, abstract), do not, in fact, reassure. He quotes Debyle, and Packer (1972) who report on nutrient losses from burned clearcuts in larch and Douglas fir forest types in Montana. He notes logging and burning temporarily impaired watershed protection, so increased erosion and overland flow resulted in nutrient losses but only for about four years. Relative to the nutrient capital in the top 30cm, values for P, K, Ca, Mg, and Na ranged from 0.5 per cent to 2.1 per cent. However, the losses are shown in the original authors' Table.

Total 4 year after burning (kg/ha)

<u>Element</u>	<u>Control</u>	<u>Treated</u>
Phosphorus	0.06	0.90
Potassium	1.53	5.02
Calcium	0.30	18.32
Magnesium	0.39	4.91
Sodium	0.75	2.68
Total	3.03	31.83

(Source: Debyle and Packer, 1972)

In a 1975 study on effects of clearcutting on stream quality in the Experimental Lakes Area north of Kenora, Ontario, Nicolson (1975) reported on several small jack pine-black spruce catchments of 35-170ha. The soil is predominantly sandy loam, with gravel and cobbles. Soils are humo-ferric podzols. Comparisons were made between uncut, one- and two- year old cut catchments. He found in the first year stream temperatures were increased an average 5⁰C (14-19⁰C), with a high of 27⁰C in July - probably lethal to most coldwater fish. Suspended sediment loads were twice those in a one-year-old cut compared with an uncut area. pH in the one-year-old cut averaged 4.97 compared with 5.76 in the uncut - a very large increase in acidity; while the stream pH in the two-year-old cut area was 5.22. Dissolved carbon in streams of the one-year-old cut was 2855 micromoles/litre, compared with 1176 micromoles/litre in the uncut. Again this is a very large increase in organic loss from the site.

All the elements he measured (11 in all) except manganese were elevated in the stream waters in the year-old cut area. In the two-year-old cut nitrate, chloride, potassium, magnesium, calcium, and iron were still elevated. Nicolson's concern was whether the increases caused

concentrations to exceed Canadian drinking water standards and they did not, but it is apparent that in this boreal coniferous area, typical of large tracts of boreal Canada, the same organic and nutritional leakage from clearcut sites as those reported for hardwood and mixed wood sites in New England, occurred.

In a subsequent paper, Nicolson, Foster and Morrison (1982) presented more data from this same study. They showed monthly flow rates to be substantially increased in the clearcut watersheds, i.e. from as little an increase as 44 per cent in July 1975 to 318 per cent in September 1975. Their Table 2 showed nutrient increases in streams continued for at least four years, for ammonium, nitrate and for total nitrogen and total phosphorus. These losses are expressed as kg/ha/week - for nitrate the undisturbed weekly loss (run-off) was 0.116, while in the one-year-old clearcut it was 0.176 and in the four-year-old clearcut it increased further to 0.252.

Similar increased losses over time occurred for Ca, Mg, K, Na, SO_4 , and Cl. The increased losses between the one-year and four-year-old clearcuts they attribute to the breakdown of the excess biomass accumulation due to the cutting and to the decomposition of the exposed forest floor.

The method of clearcutting used in this study was commercial cutting for the merchantable material of the trunk, i.e. bole-only cuts. Yet they state:

Even with conventional practices, a substantial proportion of the readily available pool of N and P for future plant growth is lost. With respect to K, Ca, and Mg, 7, 23, and 17 per cent respectively of readily available reserves in the biomass and soil are removed.

If more complete utilization occurs where any or all of the crown, stump, and roots are taken, such as in whole-tree harvesting, more than double the amount of nutrients would be removed from the site.

Losses by crop removal are of a much higher order than those lost through the draining waters. (Nicolson, Foster, Morrison, 1982, p. 83)

In the large proportion of Ontario boreal forest now subject to full-tree logging, this "more complete utilization" now occurs.

In a review of the effects of disturbances to forests on nitrogen losses, Vitousek and Mellilo (1978) have compiled a tabular comparison of the effects of clearcuts versus undisturbed adjacent forests. The original Hubbard Brooks research on the experimental clearcut stands out as causing the greatest nitrate losses but stimulated a great deal of research in subsequent years. Vitousek and Mellilo in their Table 1 (pp. 607-8), list a further 20 publications from 1972 to 1979, comprising 28 separate clearcutting examples. In every case nitrate losses increased in concentration in cut watershed streams, while where estimates were based also on per unit hectare loss, the nine examples all showed not only an increase of several to manyfold compared with uncut areas but show that the increased water flow from cut areas significantly accentuates the overall loss.

Losses in hardwood forest areas are generally much greater than nutrient losses from boreal coniferous forests, which grow, of course, on much poorer quality sites with respect to nutrient supply.

Vitousek and Mellilo (1979) suggest that the reasons for this nitrogen increase in run-off are due to:

- a) increased mineralization of N from organically bound N as a result of changed site conditions;
- b) that the normal uptake of nitrogen by plant roots is greatly reduced by cutting and removal of the crop;

- c) that the N mineralized in areas of plant uptake could be lost to groundwater or stream water, lost to the atmosphere through production of ammonia gas by microbes or then volatilized to the atmosphere, or by microbial denitrification in the soil.

Finally, regarding hydrology, the effect of fire on nutrient losses has been examined on lake and stream quality in a number of cases, notably at the Experimental Lakes Area of N.W. Ontario. Schindler et al. (1980) made one of the early reports on this. After a severe fire in black spruce and jackpine dominated watersheds in 1973, they measured increases in streamflow in one burned watershed to increase 1.8 times over previous years. A major blowdown also increased waterflow by 1.6 times that of previous years in its monitored watershed. Schindler showed nitrate levels increased by 3.4 and 9 times for the two fireswept basins, with K and P increasing to 1.1 to 2.9 times that of background. He and his colleagues go on to comment on p. 334 of their paper that:

After the fire, losses of phosphorus and nitrogen from watersheds via the streams were less than 40 per cent of the annual inputs from snow, rain and dustfall. Even with short-term increases in water yields, there appears to be little likelihood that fire-caused losses of nutrients will significantly affect the regrowth of forests. On the contrary, the extensive remineralization of organic matter in soils during the fire left high concentrations of soluble reactive phosphorus and $\text{NH}_4\text{-N}$ in the upper 5cm, little of which was removed during subsequent rainfall. (D. Schindler and G. Morrison, 1980, unpublished results)

This latter observation is interesting in that the high temperature of fire mineralizes organic matter, releasing to the ground in the ash a sudden wealth of plant-available nutrients. Many roots and underground plant parts survive fires and the site heterogeneity guarantees in most cases a rather rapid post-fire regrowth, capturing much of this inorganic nutrient source.

All this without site compaction. Losses to groundwater and streams do increase but for one or two years only in most cases, by which time nutrient capture on site has stabilized loss.

4. A comment on the B.D. Nicks Report "Influence of Clearcut Size on Frequency and Growth of Jack Pine Regeneration (Exhibit 1156 from E.B. Eddy Forest Products)

The report involved a survey of height and diameter of sample trees in two sites of jack pine restocking at Tennyson Township north-east of Espanola, and within basemap 493911 in the English River Forest north-west of Thunder Bay. At the first site an area of 128ha had been stocked with paperpot stock of jackpine seedlings five years previously, while on the second site of 132ha it had been aerially seeded seven years previously. Since the researchers found no difference in seedling growth and density across the two sites, i.e. no within-site difference except for a trend towards larger growth in the centre of the cut, the Nicks report states:

The conclusion to be drawn from this study is that restriction on the size of clearcuts, at least to levels below 130ha, will likely be of no benefit to density or growth of jack pine regeneration.

I suppose one is then expected to conclude that restriction on size of clearcuts are whimsical and without foundation. If this is the agenda, it is rather fatally flawed.

For a start, concerns about the size of clearcuts from a forest ecology point involve a complex of issues, including the amount of edge to surface cut. A square gives the least favourable ratio for wildlife movements from the closed forest, and for natural re-seeding from forest trees and native species. A long-sided rectangle is very much better, the more elongated the

better in the direction of strip cutting. The Nicks report looks at two deliberately restocked areas.

While this is fine in itself, it takes no account of the damage the clearcuts of that size did to the original forest. Large, exposed clearcuts provide a parched microclimate which dries out the normal feather mosses and lichens of the boreal forest floor. This loses a vital seedbed following clearcutting, in fact, in most fires is not lost but suffers burning of the upper few centimetres of the mosses. The charred organic remains and exposed logs and stumps, and the shadow provided by the still standing, often dead stumps after a fire also contribute to this seedbed.

Large clearcuts do not provide this. The heavy tracked equipment of modern full-tree harvesting seriously compacts the soils, crushes the living stolons and rhizomes from which regeneration occurs, and produces an unnatural overly hot site, in which the silviculturalists struggle to create a favourable seedbed.

The Nicks study which is a post-cut, post-stocking investigation tells us nothing of what the consequences of these clearcuts were to the sites, to soil organic losses, nutrient losses, changes in microclimate, alterations in wildlife numbers. Nor is microclimate measured, nor soil depth and quality, etc. It is limited by its nature to answer only one question, i.e.: What are the sizes and density of jack pine saplings on two sites which had comparable size clearcuts and were restocked five and seven years ago. Perhaps the central areas of the cuts were on deeper soil, or better soil, or suffered less compaction or any one of a myriad of possibilities, or indeed perhaps the saplings did grow as well on the central area as at

the edges. We just don't know. We also know nothing from this contribution about impact of clearcut size. Only two sites, in two different areas rather than a large number of scaled sizes, e.g. 5, 10, 50, 100, 150, 200ha, on similar sites as well as on different sites, and in different forest tree types.

Scientists and their research on aspects such as nutrition or succession are strongly and vigorously challenged by the forest industries who sometimes find the data and its interpretation at variance with the short-term economics and management of fibre extraction from the forests. This vigorous challenge is accepted. It does seem a little odd, however, that in the case of N losses from clearcuts perhaps 40 scientific papers all pointing in the same direction re losses in biomass removal and in leaching from the site are dismissed, challenged or ignored, while a one-of study of jack pine on two clearcuts is elevated to a higher plane.

BIBLIOGRAPHY

- Anderson, M., (1986) "The Impact of Whole-tree Harvesting in British Forest". Quart. Jnl. For., LXXIX:33-39.
- Dahl, E., Gjems, O. and Kielland-Lund, J., (1967) "On the Vegetation of Norwegian Conifer Forest in Relation to the Chemical Properties of the Humus Layer", Medd. Nor. Skogforskswesen. 23:503-531.
- DeByle, N.V., and Packer, P.E., (1972) "Plant and Nutrient and Soil Losses in Overland Flow Buried Forest Clearcut. pp.296-307. In. National Symposium on Watersheds in Transistion. Amer. Water Resour. Ass. Proc. Series No.14, Urbana Ill.
- Freedman, B. (1990) "Nutrient Removals During Forest Harvesting:Implications for Site Fertility." In. Woodlands Section, Canadian Pulp and Paper Association, 1990 Annual Meeting, Montreal, Quebec, pp. E51-E55.
- Freedman, B., Duinker, P.N., and Morash, R. (1986) "Biomass and Nutrients in Nova Scotian Forests, and Implications of Intensive Harvesting for Future Site Productivity". Forest Ecology and Management. 15: 103-127.
- Freedman, B., Morash, R., and Hanson, A.J., (1981) "Biomass and Nutrient Removals by Conventional and Whole-tree Clear-cutting of a Red Spruce - Balsam Fir Stand in Central Nova Scotia". Can. J. For. Res., 11: 249-257.
- Fuller, R.D., et.al., (1987) "Processes Regulating Sulphate Flux After Whole-tree Harvesting". Nature. 325:707-710.
- Gordon, A.G., (1982) "Nutrient Cycling Dynamics in Differing Spruce and Mixedwood Ecosystems in Ontario and the Effects of Nutrient Removals Through Harvesting". pp. 97-118. In. Wein, R.W., et. al. (ed.) Resources and Dynamics of the Boreal Zone. ACUNS, Ottawa, Ontario. EXHIBIT 423
- Gordon, A.G., (1981) "Impacts of Harvesting on Nutrient Cycling in the Boreal Mixedwood Forest". Boreal Mixedwood Symposium. COJFRC Symp., Environment Canada, C.F.S., Proc. O-P-9, pp.121-140.
- Hornbeck, J.W., et.al., (1975) "Strip cutting as a means of Protecting Site and Streamflow Quality When Clear-cutting Northern Hardwoods". pp.209-225. In. Bernier, B., and Winget, C.D., (eds.), Forest Soils and Forest Land Management. Laval University Press, Quebec. EXHIBIT 673
- Hutchinson, T.C., Bozic, L., and Munoz-Vega, G. (1986) "Responses of Five Species of Conifer Seedlings to Aluminum Stress". Water, Air and Soil Pollution. 31: 283-294.

Jeglum, J.K., (1980) Strip Cutting in Shallow-soil Upland Black Spruce near Nipigon, Ontario; Study Establishment and Site Conditions. Environment Canada, C.F.S., Info Report O-X-315.

Kimmins, J.P., (1977) "Evaluation of the Consequences for Future tree productivity of the Loss of Nutrients in Whole Tree Harvesting". Forest Ecology and Management. 1:169-183.

Likens, G.H., et.al., (1970) "Effects of Forest Cutting and Herbicide Treatment on Nutrient Budgets in the Hubbard Brook Watershed -Ecosystem". Ecological Monographs. Vol.40, No.1,:23-47.

Mahendrappa, M.K., et.al., (1986) "Nutrient Cycling and Availability in Forest Soils". Canadian journal of Soil Science. 66:547-572. (Exhibit 424)

Maliondo, G.M., (1988) Possible Effects of intensive Harvesting on Continuous Productivity of Forest lands. Information Report M-X-171, Forestry Canada-Maritimes, Fredericton, N.B., 26pp.

Malkonen, E., (1973) "Effects of Complete Tree Utilization on the Nutrient Reserves of Forest Soils". pp. 249-257. In. IUFRO Oslo Biomass Studies. University of Maine Press, Orono, ME.

Marek, G.T., (1975) "Ecosystem management on Shallow Sites in Lake Nipigon-Beardmore Area". pp. 195-200. Black Spruce Symposium. Environment Canada, C.F.S., O-P-4.

Martin, C.W., et. al. (1986) Clearcutting Affects Stream Chemistry in the White Mountains of New Hampshire. USDA, Northeastern Forest Experimental Station, Research Paper NE-579.

Nicks, B.D., (1988-89?) Influence of Clearcut Size on Frequency and Growth of Jack Pine Regeneration. Unpublished report, produced for E.B. Eddy Forest products, filed as EXHIBIT 1156

Nicolson, J.A., (1975) "Water Quality and Clear-cutting in a Boreal Forest Ecosystem". pp.733-738. In. Proc. Can. Hydrol. Symp. 75, National Research Council of Canada, NRCC No. 15195.

Nicolson, J.A., et.al., (1982) "Forest Harvesting Effects on Water Quality and Nutrient Status in the Boreal Forest". pp. 71-89. In. Proc. Can. Hydrol. Symp. 82, National Research Council of Canada. See EXHIBIT 414, pp. 83-101.

Nykvist, N., and Rosen, K., (1985) "Effects of Clear-cutting and Slash Removal on the Acidity of Northern Coniferous Soils". For. Ecol. Mgmt., 11:157-170.

- Schindler, D.W., et.al. (1980) "Effects of a Windstorm and Forest Fire on Chemical Losses from Forested Watersheds and on the Quality of Receiving Streams". Can. J. Fish. Aquat. Sci., 37:328-334.
- Sopper, W.E., (1975) "Effects of Timber Harvesting and related management Practices on Water Quality in Forested Watersheds". Journal of Environmental Quality. Vol.4, No.1:24-29.
- Tamm, C.O. and Hallbacken, L., (1988) "Changes in soil acidity in two forest areas with different acid deposition." Ambio Vol. 7, No. 1: 55-61.
- Tamm, C.O., (1959) "The Amount of Plant Nutrients in Soil and Stand with Special Regard to the Ecology of North-Swedish Lichen-Pine Forests". Sven. Skogsvf. Tidskr. 57:510-526.
- Timmer, V.R., and Ray, P.N. (1988) "Evaluating Soil Nutrient Regime for Black Spruce in the Ontario Claybelt by Fertilization". The Forestry Chronicle. Feb:40-46.
- Timmer, V.R., Savinsky, H.M. and Marek, G.T., (1983) "Impact of Intensive Harvesting on Nutrient Budgets of Boreal Forest Stands". pp. 131-147. In. Wein, R.W. et.al. (ed.) Resources and Dynamics of the Boreal Forest Zone. ACUNS, Ottawa, Ontario. See EXHIBIT 416a, pp.451-467.
- Ulrich, B., (1983) "A Concept of Forest Ecosystem Stability and of Acid Deposition as a Driving Force for Destabilization". pp.1-29. In. Ulrich, B. and Pankrath, J. (eds) Effects of Accumulation of Air Pollutants in Forest Ecosystems. D. Reidel Publishing, London, U.K.
- Vitousek, P.M., and Melillo, J.M., (1979) "Nitrate Losses From Disturbed Forests: Patterns and Mechanisms". Forest Science. Vol.25, No.4, pp. 605-619.
- Weetman, G.F., and Webber, B., (1972) "The Influence of Wood Harvesting on the Nutrient Status of Two Spruce Stands". Can. J. For. Res., 2:351-369. EXHIBIT 422
- Weetman, G.F., and Alger, D., (1983) "Low-site class Black Spruce and Jack Pine Nutrient removals after full-tree and tree-length logging". Can. J. For. Res., 13:1030-1036.

IN THE MATTER of the Environmental Assessment Act (R.S.O. 1980, c. 140) as amended; and

IN THE MATTER of a hearing before the Environmental Assessment Board regarding a Class Environmental Assessment for Timber Management on Crown Lands in Ontario

WITNESS STATEMENT No. 1A

ECOLOGICAL ISSUES OF FIRE, CLIMATE CHANGE,
AIR POLLUTION, AND ACID RAIN IN ONTARIO FORESTS

FILED ON BEHALF OF

FORESTS FOR TOMORROW

a coalition of

The Botany Conservation Group
of the University of Toronto

The Temiskaming Environmental
Action Committee

The Federation of Ontario
Naturalists

The Wildlands League

The Sierra Club of Ontario

TABLE OF CONTENTS

EXECUTIVE SUMMARY.....	i
5. FIRE ECOLOGY IN NORTHERN ECOSYSTEMS.....	2
5.1 Size of fires in boreal regions.....	3
5.2 Impacts of fire on the forest floor.....	5
5.3 Post-fire succession.....	7
5.4 Effect of fire on nutrient status of forests...	10
6. CLIMATE CHANGE AND BOREAL FOREST SYSTEMS.....	16
7. AIR POLLUTION, ACID RAIN AND FOREST HEALTH.....	23
REFERENCES.....	26

EXECUTIVE SUMMARY

1. This Supplementary Witness Statement has been prepared on behalf of Forests for Tomorrow for the purpose of presenting to the Environmental Assessment Board evidence regarding the ecological effects on Ontario forest ecosystems of fire, global climate change, and air pollution and acid rain effects.

2. There is general agreement in the literature that fire is a natural and very important recurring and controlling factor in many forested and non-forested ecosystems. However, when it is argued that clearcutting has a very similar "renewal" effect on a mature forest and parallels the specific effects of fire in many important ways, forest ecologists disagree with the extent and exactness of the alleged parallel impacts.

Pages 1 to 2

3. While it is true that very large fires do occur naturally, they are rare, and few fires grow to large size. Although probability of fires may be predicted for given areas, it is a better prediction that certain susceptible areas will burn many times while others will escape unscathed for long periods. Despite the role of fire suppression, the role of lightning is still important in

starting fires and in accounting for much of the acreage burned.

Pages 3 to 5

4. The intensity and duration of fire are of great importance to the survival and subsequent regeneration of boreal plant species, soil, fauna, and microbial populations. The burning of the forest floor contributes to black spruce regeneration, and has an impact on the forest floor mosses and their role in nutrient cycling.

Pages 5 to 7

5. Fire plays a major role in patterns of forest succession. Studies indicate that in the absence of fire, jack pine forests gradually give way to spruce and hardwood tree species. Forests do not simply fall apart or disappear in the absence of fire, but as the time since the last fire increases, conditions change to favour replacement of one sort of forest by another. The species which develop through this succession vary with the type of species in the replaced forest. Prescribed burning has potential usefulness in assisting jack pine regeneration after harvesting.

Pages 7 to 10

6. One of the major influences of wildfire is on the nutrient availability for plant uptake at a site. The effect of forest fires is to cause a simultaneous release of soluble plant nutrients and a reduction of acidity to one more favourable for plant uptake and less conducive to damage from toxic elements such as aluminum.

Pages 10 to 12

7. During hot fires with temperatures above 500 degrees Centigrade, losses in the form of gases, volatiles and in smoke of several nutrient elements are significant. These include potassium, carbon, sulphur, phosphorus, and boron.

During cooler fires, much of the nutrients remain on site, resulting in the sudden availability of a large pool of bases for the uptake of surviving roots, stolons, suckers, and seedlings.

Pages 12 to 13

8. Clearcutting does not emulate these nutrient effects, the effect of fire in preparing a seed bed suitable for black spruce seedling establishment, or the reduction of competition from hardwood competitors that results from fire.

Page 13

9. Nitrogen is the macronutrient most susceptible to loss during a fire. In the post-fire succession nitrogen on site may be significantly reduced because of the decrease in soil nitrogen. However, for a few months to a few years, the available nitrogen level is increased since much that was tied up in the organic matter is made soluble and available. Just as a rise in the nitrogen level in streams and lakes after clearcutting occurs, fire has similar response in regard to nitrogen.

Page 14

10. Most of the elements carried aloft in the smoke of a boreal forest fire return to the ground elsewhere in the boreal forest. This re-deposition of nutrients from smoke is again quite different from the uni-directional removal from the site of the same nutrients in harvesting, especially in full-tree harvesting.

Pages 14 to 16

11. Scientists have been increasingly concerned with the build-up of greenhouse gases in the earth's atmosphere, including carbon dioxide, and methane, and the thinning of the ozone layer with attendant increases in ground-level ultra-violet radiation. This radiation is biologically extremely active. Ozone and oxidant levels are increasing in the lowest part of the atmosphere. These very reactive

gases have well known deleterious effects on plant growth and performance, and have direct impacts on forests.

Pages 16 to 18

12. Many scientists believe we are into the warming trend associated with the greenhouse gases build-up , and there is agreement that the greatest warming effects will be in the upper latitudes. While there is reasonable confidence in the anticipated occurrence of global warming, the speed and extent are very difficult to predict confidently, especially as they will be influenced by human regulatory response to the anticipated changes.

Pages 18 to 20

13. Possible consequences of climate change for forests include changes in species distribution and species ranges, milder winters leading to increased insect attack, hotter summers giving more rapid tree growth but increasing the fire risk, drying out of the soils in central boreal regions with effects on nutrient cycling, changes in wildlife habitat, and migration northward of Great Lakes St. Lawrence hardwood species.

Pages 20 to 22

14. It seems vital that the future management of our forests in all aspects from harvesting practices to

silviculture to decisions on what genetic resources to use, take impending climate change into account.

Page 23

15. The effects of regional air pollution are difficult to assess. A good many of the present pollutants of the air are gases which are phytotoxic. In Central Europe soil acidification has been tied to acidic deposition, and leaching of nutrients from the rooting zone and directly from the foliage has been documented under many forest types.

Ozone is considered the major air pollution problem for USA forests, and undoubtedly is impacting Canadian forests also. A warming atmosphere will cause increases in ozone and in nitrogen oxide problems in the future.

Air pollution is considered to be a major factor in forest decline and dieback of Quebec and Ontario maple forests. Air pollutants have caused major damage to forests in the past and it will be essential to recognize their potential as stresses on the forests in the future.

16. Dr. Tom Hutchinson will attend the hearing to testify to the contents of this Witness Statement.

Pages 23 to 25

5. FIRE ECOLOGY IN NORTHERN ECOSYSTEMS

Many excellent reviews of the effects and occurrence of fires in boreal ecosystems exist, several of which consider the ecological effects of fires in other forested ecosystems also (e.g. Ahlgren and Ahlgren (1960), Wein and MacLean (1983), Cayford and Macrae (1983), Rowe and Scotter (1973)). Kimmins (1987) also provides a very useful summary of the role of fire as a major natural disturbance in his text on forest ecology.

There is general agreement that fire is a natural and very important recurring and controlling factor in many forested and non-forested ecosystems. In the boreal forest system, on prairie grasslands, in Mediterranean climates, in vegetation such as the chaparral of California, the effect of fire is a dominant one in determining the vegetational composition and paths of succession. In testimony on behalf of the MNR and the forest industry, the natural occurrence and role of fire has been emphasized. It has also been argued, most particularly by I. Methven, that clearcutting has a very similar "renewal" effect on a mature forest and parallels the specific effects of fire in many important ways. It is at this point in the MNR argument that disagreement with forest ecologists begins, regarding the extent and exactness of parallel impacts. When the parallels are pushed to the extreme in arguing that fires of

up to 250,000 hectares occur so clearcuts of enormous size can be justified ecologically, that disagreement is greatest.

There can be no doubt that in many forest communities of the boreal, fire is a normal, important, perhaps dominant disturbance, and many of the species are, in fact, adapted to this recurring stress. Jack pine is perhaps the outstanding example in northern Ontario and Quebec, while lodgepole pine is a remarkably fire-adapted species in the west. Black spruce and to a lesser extent white spruce forests are also the result of post-fire successions. Rowe and Scotter (1973) noted the characteristics contributing to successful regeneration following fires for various coniferous species, and ranked them as showing post-fire success in the order of jack pine >black spruce >tamarack >white spruce >balsam fir. As the frequency of fire decreases in a region, the opportunity for balsam fir to become a major component of the vegetation increases. In regions where fire is likely to occur at shorter intervals, e.g. say every 35 years on average, then tree species with successful adaptations for re-establishing themselves after fire are likely to predominate.

5.1 Size of fires in boreal regions

Before describing more specific effects of forest fires, it is useful to consider their frequency and size in the boreal regions of Canada. In the more southerly hardwood forests, while fires do occur, their size and frequency are a good deal less than in the boreal. Because of large human populations living in the hardwood areas, fire suppression is also vigorous while the accumulated loads of combustible fuel on the forest floor is much less than in the boreal, due largely to more rapid litter decomposition.

Most fires now are initiated by man's activities and a policy of fire suppression is in place in the provinces. Only in the Territories in certain regions is no attempt made to control and extinguish fires. While it is true that very large fires do occur naturally, they are rare. It seems extreme to argue that because some huge fires occur from time to time that huge clearcuts are justified as merely simulating a natural phenomenon. If the naturalness of fires is to be used in determining size of clearcuts, then the normal or average size would seem a much more logical or reasonable way to proceed. It is useful to quote Rowe and Scotter (1973) in this regard (p. 453):

Few fires grow to large size. All begin at a point and most are still small when extinguished naturally or by man. Scotter (1970) found that 60% of the fires in his subarctic forest samples were less than 10 acres in size

and analysis of 8 years of fire reports for Saskatchewan shows 82 and 88% of all fires were under 100 acres in size for the southern or northern districts respectively. In all of Canada for the 7-year period 1961-67, 85% of all fires were 10 acres or less in size. These figures suggest good reason for the patchiness of vegetation.

They point out that over long periods of time the much rarer large fires burn the largest area overall. They quote from work of VanWagner who produced statistics for the average annual burn in Canada showing it to be 0.3% of the whole forest area, which indicated that on average each forest area will burn once every 300 years.

In more fire-susceptible parts, the probability for fire in each area is once every 100 years. In both cases it is a better prediction that certain susceptible areas will burn many times while others will escape unscathed for long periods.

Undoubtedly, in some of the upland jack pine forests on well-drained sands the fire frequency is 35-50 years.

Indeed, several authors have commented that it is difficult to find forests in Canada in boreal region of more than 300 years of age. In the northwestern boreal region the oldest forests are in the range of 300 years and are composed of white spruce. They occur as pure stands on the moist floodplains of the rivers, where fire does not have ready access.

While fire suppression is exercised as policy in most jurisdictions, the role of lightning is still important in

starting fires and equally in accounting for a good deal of the acreage burned. Rowe and Scotter (1973, p. 447) note that in Alberta in 1967 lightning accounted for one third of 1236 forest fires. In Ontario dry lightning fires at the end of the first week in June were chiefly responsible for fire and, later in June, 25 of the year's fires burned 93 per cent of the year's total average consumed by fire. In the period 1961-67, 27 per cent of the area burned. In the Territories in this period, 44 per cent of all fires were caused by lightning, consuming 78 per cent of the area burned.

5.2 Impacts of fire on the forest floor

In terms of the impact of fire, the intensity of the fire and its duration are of great importance to the survival and subsequent regeneration of the boreal forest plant species, as well as to the soil, fauna and microbial populations. Of particular importance are the depth to which the duff of the forest floor is burned and the temperature that is achieved in this burn. In most, rather fast-moving, summer and spring fires, the patchiness of the burn is striking. While for example, in a black spruce forest, areas of mineral soil are exposed, in many other parts the surface of the organic layers only is burned, and some patches, in wet low-lying hollows or in shadows of rocks, may be virtually unburned.

Undoubtedly, the most damaging in terms of survival of underground roots, rhizomes, and seeds, are those rather slow-moving fires that burn deeply into the organic mat, killing roots and buried seeds, as well as the tree stumps from which suckers would otherwise grow. The burning of much of the forest floor in black spruce areas creates an ideal seed bed for subsequent regeneration, as the fire destroys the roots of many of the potential broad-leaf competition and stimulates black spruce layering, as well as providing an ideal seed bed for future spruce seedling establishment. The adaptations of jack pine to post-fire succession have been described at length in the literature. These include serotinous cones which need high temperature stimulation to open; seedlings which are able to establish at high light intensity (but are poor competitors); and needles with resins that combust readily.

Much less well known is the important role in nutrient cycling of some of the lower plants which often cover a very large percentage of the forest floor in mature pine and spruce forests. These include the feather mosses and the Cladina lichens, commonly called reindeer lichens. Huge tracts of our boreal forests have a ground cover of these plants, and through this layer, all downward movement of water and dissolved nutrients occurs. Timmer (1970) showed that the feathermosses controlled and contributed

significantly to nitrogen cycling in Ontario boreal forests. It seems that they have an important role in phosphorus and calcium status of the forest floor also. After a fire, much of the lichen and feather moss cover is destroyed but pockets survive in the mosaic that is left. Ahlgren (1959) studied post-fire successions in lichen woodlands in Newfoundland and noted that it took from 30 to 89 years before a reindeer lichen phase was re-established and that the mature phase of Cladina alpestris (stellaris) took 80 years or more (ie. 60 - 80 years) to re-establish. Forest logging cycles of less than this are likely to eliminate this mature phase of the forests, and, of course, will eliminate the rare old growth forests.

In Ontario we have found that 25-35 years post-fire is necessary before feather moss communities re-establish in jack pine in the Kirkland Lake - Timmins region.

5.3 Post-fire succession

With respect to post-fire succession in jack pine, Woods and Day (1977) studied the jack pine stands of Quetico Provincial Park, in order to determine the patterns of replacement in the presence and absence of fire. They concluded that large fires were the major factor which had initiated the stands of jack pine of different ages in the

park. The stands ranged from 14 to 160 years. In the absence of fire they concluded that jack pine would be gradually replaced by shade-tolerant species. At 15 years, jack pine dominated the system, with stems at 10,000 per hectare, being 20 times as abundant as aspen. Beneath the overstorey, black spruce provided an understorey. At 45 years post-fire, jack pine and aspen still dominated the overstorey but with an understorey of black spruce, white birch, and sugar maple. The pine and aspen were not regenerating. Balsam fir was now included in the understorey. At 105 years, the pine and aspen canopies were in decline (they describe this loss of vigour as decadence). Black spruce and sugar maple were replacing the declining trees. In the 135- and 165-year-old forests, the original jack pine and aspen were almost completely replaced by the understorey trees.* At 165 years only a few large "decadent" jack pine remained in a predominantly spruce-balsam fire-sugar maple-red maple forest. It seems from this and numerous other studies (see Cayford and Macrae, 1983), that in the absence of fire, jack pine forests gradually give way to spruce and hardwood tree species. In terms of short rotation jack pine forests of 35-50 year replacement times, conditions should favour jack pine. Silvicultural techniques for jack pine regeneration are very much easier to achieve than is the case for black or white spruce, though clearcutting differs from wildfire in sufficiently

important ways to create new problems of hardwood competition, seeding in, nutrient status, and changed pH.

It is also apparent that forest do not simply fall apart or disappear in the absence of fire, but that as the time since the last fire increases conditions change to favour replacement of one sort of forest by another. It is not true that jack pine is inherently incapable of living for more than 150 years. Heinselman (1973) reported on studies in the forests of the Boundary Waters canoe area of Minnesota. He suggested that black spruce would eventually replace jack pine in maturing forests in the absence of fire, and with a feather moss ground cover.

Where balsam fir is significant in association with jack pine, the succession will be towards a balsam fir-white birch-white spruce type with a tall shrub layer.

He noted that complete replacement did not occur due to survival of ancient jack pine trees. In 1970 he found scattered jack pine in a stand that burned in 1727, i.e. 243 years old, and in the same year he found numerous 215-year-old jack pine in a stand burned in 1755. Thus, Cayford and Macrae (1983) point out:

It is evident that individual jack pine can persist as a scattered overstorey for at least 210-250 years without fire.

These reports on the longevity and persistence of a tree often reported to demand fairly short intervals between

burns, because of its allegedly short-lived nature, has relevance to discussions of old-growth forests where. Often the old-growth jack pine forest is healthy and includes tree species accepted to have much greater longevity than jack pine, e.g. white pine, red pine, balsam fir, sugar maple, hemlock, etc.

Cayford and Macrae (1983) also comment on the potential usefulness of prescribed burns in assisting jack pine regeneration after harvesting.

Jack pine regeneration silviculture began in the 1930s when it became evident that the species would not regenerate adequately after harvest cutting unless special silvicultural practices were undertaken. Reasons for failure of jack pine to regenerate on the cutover sites have included non-receptive seedbeds, insufficient moisture, inadequate seed supply, insufficient light, and excessive plant competition.

Research into the use of prescribed burns began in Ontario and Michigan in the 1940s and '50s, and initial results suggested the technique had potential. Further research was conducted in the 1960s and '70s in Minnesota, Ontario, Manitoba, and Saskatchewan. The results are still being evaluated (1983), but unfortunately, practically no new experimental work has been undertaken in recent years.

5.4 Effect of fire on nutrient status of forests

Undoubtedly one of the major influences of wildfire is on the nutrient availability for plant uptake at a site. The

combustion of the litter (duff) on the surface of the soil and the burning of the organic matter release many elements essential for plant growth, often in the form of oxides, into the upper soil. As Kimmins (1987) points out, when fire oxidises organic compounds in which many essential nutrients are stored in a reservoir which is otherwise difficult to tap, the result is a sudden burst of availability of both anions and cations. The smoke and vapour from the fire itself carries away much more of the anions, especially nitrogen, phosphorus and chloride, than of cations such as calcium, magnesium and potassium. The ash left consists largely of the soluble oxides of the latter elements, which are changed to carbonates and generally cause a rise in pH, i.e. the result of fire is to raise the surface soil pH. In most boreal forest sites, this change favours plant growth. This is because most of our forests in the north grow on acidic sites, where the coniferous needles together with the bedrock (granites) or raw deposits, cause the pH to be low. Forest growth itself, as a result of roots extracting bases from the soil solution and releasing hydrogen ions in replacement, causes a change in soils towards acidification. The effect of forest fires is to cause a simultaneous release of soluble plant nutrients and a reduction of acidity to one more favourable for plant uptake and less conducive to damage from the effects of toxic elements such as aluminum.

Viso (1974) reported a pH increase of 2-3 units in the forest floor following burning, and this effect was prolonged over the post-fire succession. He estimated it took 50 years before the soil pH returned to that at the time of the fire. He noted also that while the pH effect was greater in the surface soils, in the underlying mineral soil there was less effect, but there remained a pH increase of 0.4 units for 20 years¹. Even after 50 years there was still an increase of 0.2 pH units. These favourable effects in reducing soil acidity are very widely reported from Scandinavia, Scotland and North America. This is one of several key areas in which clearcutting does not simulate fire, though as noted earlier it sometimes causes a small change in this direction. The effect of pH rise following clearcutting also takes longer to achieve and is shorter lived.

During hot fires with temperatures above 500°C, losses in the form of gases, volatilized and in smoke, of several nutrient elements, are significant. Potassium is one of these. Carbon is lost as carbon dioxide. Indeed major forest fires are a very significant contribution to global emissions of CO² each year, adding to the greenhouse gases from other sources. Sulphur is lost as the gas sulphur dioxide and phosphorus also is lost to the atmosphere.

Boron is a micro nutrient which is also lost during fire. Since, in parts of Sweden boron deficiency is a limiting factor for forest growth, this fire induced loss could be of significance. In high temperature fires also, many other elements are lost as fly ash particles in the smoke. In cooler fires much of the nutrients remain on site. As a result calcium and magnesium often increase significantly in concentration in the rooting zone due to ash deposition from vegetation on the site. The sources of this are combustion of foliage, branches, boles, bark, and litter. A large pool of bases is suddenly made available for the uptake of surviving roots, stolons, suckers, etc. and for seedlings which germinate and establish in the first few months and years following the fire. This situation is not properly simulated by clearcutting.

The effect of fire in preparing a seed bed suitable for black spruce seedling establishment is not simulated by clearcutting either, as it is by fire.

Nor does clearcutting kill and reduce competition from hardwood competitors as does fire. This lack of parallel or similar chemical or physical influences cause major silviculture problems for re-establishing forests after clearcuts. Other detrimental influences are also introduced by clearcutting including soil compaction and removal of

nutrients from site in the biomass, etc.

Of all the macronutrients, nitrogen is most susceptible to loss during a fire. In the post-fire succession nitrogen on site may be significantly reduced because of the decrease in soil nitrogen. However, for a few months to a few years, the available nitrogen levels are increased since much that was tied up in the organic matter is made soluble and available. Nitrogen is lost in the gases as nitrogen oxides, especially from high temperature fires, and is also readily leached out of the soils into the drainage waters of the waterbed and into the ground water. The rise in nitrogen level in streams and lakes following clearcutting has already been noted in this submission. With regard to nitrogen fire has a similar response, whereas this is not the case regarding calcium and magnesium.

During a fire often much of the particulate matter in the smoke is deposited locally. Clearly, the elements lost as gases, aerosols and particulates will return to the ground somewhere. Most of the elements carried aloft in the smoke of a boreal forest fire return to the ground elsewhere in the boreal forest. Much will be within 50 - 100 km from the fire source, and when air temperatures are low and/or the fire is not a very hot one, then much can be re-deposited quite close to source. Gases such as carbon dioxide,

sulphur dioxide, nitrogen oxides will obviously be carried much greater distances. Fires at one location in the boreal can be viewed as a source of aerially deposited calcium, potassium, boron, phosphorus, zinc and manganese for areas elsewhere - a form of recycling. However, there is a loss and the gain is dependent upon atmosphere deposition over many years. It is noteworthy, however that this re-deposition of nutrients from smoke is again quite different from the uni-directional removal from the site of the same nutrients in harvesting, and especially in full-tree harvesting.

Evidence that the smoke from a forest fire deposits elsewhere carrying nutrients with it is obtained from downwind rainfall and dustfall collections. Kimmins (1987) reports that rainfall falling through smoke in Idaho following a Douglas fir ponderosa pine fire had concentrations of nitrogen, potassium, calcium, magnesium and sodium which were 21, 38, 19, 27 and 71 times higher respectively than rain before the fire.

The effect of fire in producing a seed bed suitable for re-establishment of seedlings of several tree species and in opening up cones from which seeds inoculate the site is well known. In clearcutting, hardwoods left standing are a seed source as fire is not required for seed release, while cones

of conifers occur in slash in cutover stands. Serotinous cones of jack pine will release seeds in exposed cutovers, but not nearly to the same extent as after fire (Walker and Sims 1984).

It is clear that one major difference between post-fire conditions at a site compared with post-clearcutting is that the clearcut fails to reproduce the favourable conditions regarding nutrient availability that fire achieves. This difference also includes creation of a more favourable nutritional status as a secondary consequence of reduction in acidity following fire. Fire also influences the forest floor in a favourable direction for the post-fire succession, both regarding seed bed preparation, competitor survival, hardwood invasion, soil pathogens, stimulation of seed release, etc. The result of these differences, especially for seedbed preparation and control of hardwood competitors, provide an expensive silvicultural challenge in re-establishing cut over forests.

6. CLIMATE CHANGE AND BOREAL FOREST SYSTEMS

A great deal of attention has been given over the past five years to the build-up of greenhouse gases in the earth's atmosphere and to the potential effects this changed

atmospheric composition is likely to have on the climate of the earth, especially in the higher latitudes. The greenhouse gases of particular impact at the present are carbon dioxide and methane, though several others have similar properties of absorption of radiation in the longer wavelengths. In addition the problem of depletion of stratospheric ozone has been measured and the ozone holes over the Antarctic in particular are causing concern. The release of chloro-fluorocarbons, especially from refrigerant coolants and from aerosol can propellants have been shown to play a catalytic role in this destruction of ozone, which in the upper stratosphere acts as a shield against excessive quantities of ultra-violet light reaching the surface of the earth. A thinning of the ozone layer is already causing increases in ground-level ultraviolet radiation in the higher latitudes of both the northern and southern hemispheres. This UV is biologically extremely active, influencing the immune system in mammals, affecting soil microbial activity, affecting photosynthesis and reproduction in phytoplankton seed germination and production of antibodies..

While this ozone depletion is taking place in the stratosphere, in the lower troposphere (the lowest part of the atmosphere) over much of Europe and North America, ozone and oxidant levels have been increasing. These are again

very reactive gases, with well known deleterious effects on plant growth and performance at levels and exposure times which are increasingly being met in the summer and autumn months. The sources of these gaseous oxidants are nitrogen oxide gases emitted into the atmosphere at ground-level to a few hundred metres above from automobile exhausts and from all high temperature combustion processes: incinerators, central heating, plants, power generation, smelters, etc. This in combination with hydrocarbons from automobile and aircraft exhausts and from oil refineries and all other uses of oil as an energy source, and in the presence of sunlight causes production of oxidant gases. These gases have direct impacts on forests, as has been noted from the early 1950s on ponderosa and jeffrey pines in the San Bernardino Mountains of California.

The warming effects of greenhouse gas build-up are estimated to be from 3 to 5° by the time an equivalent doubling of 1960 CO₂ levels is achieved. Equivalent doubling refers to the additive effects of trace gases which have properties in terms of contributing to global warming. The time will take cannot be accurately estimated but at present emission rates is likely to be between 2030 to 2050, i.e. only 40 to 60 years away. Already many scientists believe we are into this warming trend. Hanson of NASA points out that five of the hottest years in the past 140 years all occurred in the

1980s, with 1988 the hottest recorded. Of course, this is not proof. Many other observations have been made which all point in the same direction.

There is agreement that the greatest warming effects in the summer months will be in the upper latitudes, i.e. 50 to 70 degrees North and in the centres of continents. A global circulation model run for North America suggested that an equivalent doubling of CO₂ would give an annual average growing season increase of +9°C in the Winnipeg-Kenora region, while Quebec would experience a 3-5°C increase. These impacts are dramatic and previously non-experienced changes occurring in the lifetime of forests being planted now.

While there is reasonable confidence in the anticipated occurrence of global warming, the speed and extent are very difficult to predict confidently, especially as they will be influenced by human regulatory response to the anticipated changes. Most of the responses to the carbon dioxide threat have been entirely talk, generally in the area of how to cap emissions in the industrialized world at present levels, rather than how to reduce them from the present. A notable exception are the treaties and protocols on chloro-fluorocarbons which have been developed in the past three years and which aim to ban all production of CFC's within

the next 5-9 years. Since these compounds are produced by a small number of manufacturers their reduction is relatively easy to achieve compared with that of carbon dioxide which is produced by all combustion processes, from domestic and industrial sources, from all plant and animal respiration and from wild fires.

Methane sources include those from microbial decomposition in wetlands, marshes, swamps, bogs, and from animal metabolism - feedlots, sheep in New Zealand, etc.

Consideration is now being given to the consequences for forestry and forests of the anticipated large and rapid climate changes. The concerns encompass change in species distribution and species ranges, milder winters leading to increased insect attack, hotter summers giving more rapid tree growth but increasing the fire risk, drying out of the soils in central boreal regions with effects on nutrient cycling, due to hot summers and low winter snowfalls, changes in wildlife habitat, especially changes in wetlands, and migration northward of Great Lakes St. Lawrence hardwood species.

Many regenerating forests from the present will experience climatic shifts in the next 30 to 50 years that will make the habitat and climate in which they find themselves

unsuitable for either optimal performance, reproduction or survival. The hot dry summers which will increase in probability will make the drought conditions of 1988 of more frequent occurrence. It now seems imperative that despite the difficulties in absolute predictions, that the forest industry in Canada find out as much as it can of the likely consequences of climate change and takes these into account in developing management plans for the future. It is cavalier and irresponsible to dismiss the topic as either "another environmental scare" or as too fraught with uncertainty to be worth considering. The probability of the occurrence of climate change of large magnitude is high.

In a recent paper by Wheaton et al (1989) from the Canadian Climate Centre, Environment Canada, the authors conclude, based on plausible models:

The potential northward shift of the boreal forest indicate considerable shifts in the forest's climate zones as a result of "greenhouse gas" warming. The potential northward shift in the northern boundary ranges from 100 to 700 km. The potential northward shift in the southern boundary ranges from 250 to 900 km.

This means that increasingly, regeneration in the southern parts will be with progeny less and less suitable for the future.

Examples of potential biomass productivity changes include decreases from normal and southern locations of about two to twelve per cent and increases to about 50% above normal for gridpoints in the northern part of the predominately forest zone.

The forests growing at the edges of the climate zones, in marginal climatic areas are likely to be the first to be in difficulty. It has taken 10,000 to 12,000 years since the retreat of the last glaciation to allow migration of forest species from the south to the present boreal limits. The northward migration of the Great Lakes St. Lawrence forest and the considerable expansion of these forests cannot take place in 30 - 40 years. We need to know as much as possible about climate change for this period so we can plan for change.

D. Pollard (1989) in a report for Canadian Forest Industries (CPPA Woodlands) notes:

Pests and disease will not be the first or only sign we have that climate is underway, but they are extremely sensitive to climatic variation and will undoubtedly create some of the earliest visible impacts of climate change.

Regarding increased forest fire risks Street (1989) reports:

The general trend of the analysis indicates that in all regions of Ontario the forest fire season under the proposed climatic conditions will be longer, starting during the month of April and continuing into the month of October. It is evident that the fire seasons will generally be more severe than those under the current climatic normals. In addition to a general increase in overall severity, the analysis suggests that there will be a shift in the timing of the most severe portion of the fire season. Traditionally, the months of May - July have been the most severe. However, under the modelled climate of the two change scenarios, the most severe portion of the fire season will shift to later in the season, typically July, August and September.

It seems vital that the future management of our forests in all aspects from harvesting practices to silviculture to decisions on what genetic resources to use, take impending climate change into account. This means being very well informed. I reiterate the comment of Peter Duinker (1990):

If significant climate changes occur over the next 50 - 75 years, forests throughout the world will undergo massive adjustments, many of which will in the short-term be undesirable. Forest management has high potential for mitigating these effects, but only with support of insightful policy initiatives that take account of potential climatic changes.

7. AIR POLLUTION, ACID RAIN AND FOREST HEALTH

Aside from the devastating impacts of intense local point sources of air pollution on forests, eg. sulphur dioxide emissions from the smelter stacks at Sudbury which killed the white pine forests for 15 km in all directions, the effects of regional air pollution are much more difficult to assess. Certainly, a good many of the present pollutants of the air are gases which are phytotoxic. Examples are ozone, oxidants, nitrogen oxides, sulphur dioxide and peroxides. In addition, when they are deposited in rain or scrubbed from the air as polluted snow, they impact the leaves of crops and native vegetation. The occurrence of acidic deposition has been a very large topic of research and

concern for 20 years. In Central Europe soil acidification has been tied to acidic deposition. Leaching of nutrients from the rooting zone and directly from the foliage - of bare elements such as calcium, magnesium and potassium, has been documented under many forest types. If the soils are nutrient poor such as shallow podzols, or well drained sands, this leaching is likely to decrease growth and add additional stress for the trees. A very strong case has been made in Germany linking acidic inputs with increased mobilization in the soil of toxic aluminum, causing root damage and culminating in magnesium deficiency as Norway spruce decline. This specie is the major economic tree in Scandinavia and Central Europe, together with Scotch pine.

In the USA the ozone has been widely monitored. While it is generally associated with Los Angeles smog, the 1980's have shown it very widely distributed and increasing in concentration. It is considered the major air pollution problem for USA forests, and undoubtedly is impacting Canadian forests also. Nitrogen oxides represent a further problem. A warming atmosphere, with increased warmer temperatures and more sunlight, will cause increases in ozone and in nitrogen oxide problems in the future.

The occurrence of forest decline and dieback in Quebec and Ontario maple forests has received a lot of publicity.

Sugar maple decline is prevalent and serious in Quebec and in parts of Ontario (and adjacent USA states). Air pollution is believed to be a major factor in this, with other contributing factors perhaps including insect defoliation, climatic extremes, etc. Acid rain, with the leaching of nutrients may also be a factor, causing soil acidification in the rooting zone.

Certainly, air pollutants have caused major damage to forests in the past and it will be essential to recognize their potential as stresses on the forests in the future. It would be wise to keep in mind the fact that air pollution impacts at chronic levels are likely to add to the stresses forests face, especially to nutrient stresses.

REFERENCES

- Ahlgren, C.E. (1959). Some effects of fire on forest reproduction in north-eastern Minnesota. J. For. 57:194-202.
- Ahlgren, I.F. and C.E. Ahlgren (1960). Ecological effects of forest fires. Bot. Rev. 26:483-533.
- Cayford, J.H. and D.J. McRae (1983). The ecological role of fire in jack pine forests. In: The Role of Fire in Northern Circumpolar Ecosystems. R. Wein, R. Riewe, and I.V. Methven eds. Wiley, N.Y. Chapter 10, pp. 183-199.
- Duinker, P. (1990). Climate change and forest mangement, policy, and land use. Land Use Policy, April issue.
- Hienselman, M.L. (1973). Fire in the virgin forests of the boundary waters canoe area, Minnesota. Quaternary Research 3:329-382.
- Kimmins, J.P. (1987). Forest Ecology. Macmillan Publishing Co., N.Y. 531 pp.
- Pollard, D. (1989). Climate change and its effects on forests. CPPA Woodlands, Canadian Forest Industries, May issue.
- Rowe, J.S. and G.W. Scotter (1973). Fire in the boreal forest: Quaternary Research. 3:444-464.
- Street, R.B. (1989). Climate change and forest fires in Ontario. Presented at the 10th Conference on Fire and Forest Meteorology, April 17-21, Ottawa. pp. 177-182.
- Timmer, V.R. (1970). To follow shortly.
- Viso (1974). To follow shortly.
- Walker, N.R. and H.P. Sims (1984). Jack pine seed dispersal from slash and seedling performance on prepared seedbeds. Northern Forest Research Centre, Canadian Forestry Service, Information Report NOR-X-259. 13 pp.
- Wein, R.W. and D.A. MacLean (1983). An overview of fire in northern ecosystems. In: The Role of Fire in Northern Circumpolar Ecosystems. R.W. Wein, R. Riewe, and I.R. Methven eds. Wiley, N.Y. Chapter 1, pp. 1-18.
- Wheaton, E.E., T. Singh, R. Dempster, K.O. Higginbotham, J.P. Thorpe, G.C. VanKooten, and J.S. Taylor (1989). Exploring the implications of climatic change for the boreal forest and forestry economics of western Canada. Climate Change Digest, Environment Canada, CCD 89-02, 18 pp.

Woods, G.T. and Day, R.J. (1977). A summary of the fire ecology study of Quetico National Park. OMNR, Forest Fire Control Bureau, Toronto. Quetico Provincial Park Fire Ecology Study, Report 8, 39 pp.

CA20NEA 87W01

Ontario. Environmental Assessment Board.

Witness Statement No.1

ECOLOGICAL IMPACTS OF TIMBER MANAGEMENT ACTIVITIES

ECOLOGICAL ISSUES OF RIDE CLIMATE CHANGE AIR

**RESOURCE CENTRE
INST. FOR ENVIRON'L. STUDIES
UNIVERSITY OF TORONTO**



